PATENT SPECIFICATION

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DRAWINGS ATTACHED

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(54) ROTOR ASSEMBLY

(71) We, THE BOEING COMPANY, organised under the laws of the State of Delaware, United States of America, of 7755 East Marginal Way, Seattle, Washington, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement: —

This invention relates to rotor assemblies for of the articulated variety for use with vertical lift aircraft.

Conventional articulated rotor assemblies have generally been of a complex construction employing many elements in the load path extending from the rotor shaft to the rotor blade. These assemblies generally employed three separate hinges for each blade so as to permit the blade to rotate about a pitch axis, and to pivot about lag and flapping axes. It was usually necessary to provide each hinge with precision rolling element bearings, a source of lubrication, and suitable seals. The resulting structure was heavy, costly to produce, and expensive to maintain. Further, normal procedures usually required substantially clean facilities for assembly, inspection, and over-haul. This requirement made field maintenance difficult, particularly in view of the fact that each hinge with its large number of component parts was susceptible to the effects of adverse environments.

To improve the characteristics of articulated rotor hubs, various constructions for retention of rotor blades have been proposed which employ resilient bearings including a plurality of concentric spherical plates and elastomer bonded together in alternate layers. In these instances, a resilient bearing is so constructed that the centrifugal force of the blade, upon rotation of the hub, results in compression of the elastomer within the bearing while the resilient nature of the bearing further permits pitch, lag, and flapping motions of the blade. The layers of elastomer are sufficiently thin to withstand high normal pressures, without bulging outwardly, that is, in directions normal to forces applied to the bearing, and the ability of each layer to deflect in shear in order to accommodate blade motions about the pitch, lag, and flapping axes, is substantially independent of the normal pressures applied to the bearing. In this manner, the resilient bearing is able to provide the required blade motion while restraining the centrifugal loads resulting from rotation of the rotor assembly.

Although such resilient retention bearings are highly desirable due to their simplicity and reduced weight and cost over conventional bearings, it has been found that this very feature of resiliency often results in imbalance within the rotating rotor hub which in turn gives rise to undesirable vibrations. Specifically, with the known constructions, it has been difficult to "track" the different blades of a multiple-blade rotor system, that is, to assume that the tips of each of the blades would proceed along a uniform path. The present invention proposes a hub construction which retains all of the inherent desirable features of the resilient retention bearing construction while avoiding the difficulties described.

According to the present invention, there is provided a rotor assembly for a vertical lift aircraft comprising a rotatable hub member, a rotor blade adapted to provide lift to said aircraft upon rotation of said hub member, retention means mounting said blade on said hub member and including a universal bearing having a fixed centre and supporting said blade for pivotal movement about a lag axis and about a flapping axis and for rotation about a pitch axis, said axes intersecting at said fixed centre, and a resilient bearing restraining said blade against centrifugal forces inposed in response to rotation of said hub member and cooperating with said universal bearing to permit pivotal and rotational movement of said blade about said fixed centre.

Preferably, the universal bearing permits longitudinal motion of the blade and thus is not loaded by centrifugal force and the resilient bearing includes a plurality of concentric part-spherical plates and elastomer bonded together in alternate layers so as to be generally concentric with the universal bearing.

Enabling the blade to move freely about the pitch and lag axes when assuming full flap or full droop conditions, a roller is mounted on the blade coaxial with the pitch axis and engageable, respectively with a flap stop and with a droop stop integral with the hub. Also, a lag damper extends between the hub and a universal joint on the blade coaxial with the pitch axis so as to be fully effective to dampen blade movement about the lag axis, but substantially ineffective to dampen blade movement about either the pitch or flapping axes.

In order that the invention may be well understood there will now be described an embodiment thereof, given by way of example only, reference being had to the accompanying drawings in which: —

Figure 1 is a side elevation view, partly in section, of a rotor assembly according to the invention;

Figure 2 is a top plan view of the rotor assembly illustrated in Figure 1, certain parts broken away and in section for greater clarity; and

Figure 3 is a detail view of parts shown in Figures 1 and 2.

Referring initially to Figures 1 and 2, a rotor assembly includes a drive shaft 10 adapted, upon rotation, to rotate a hub member 12. A plurality of blades 14 are attached to the hub 12 by means of a retention mechanism 16 whereby rotation of the drive shaft 10 and the hub member 12 is imparted to the blades 14.

The retention mechanism 16 includes a universal bearing 17 in the form of a ball 18 rotatably mounted in a socket 20 fixed to a support member 22 spaced substantially radially outward from a central portion 24 of the hub member 12. The socket 20 is preferably provided with a suitable bearing surface for firmly engaging the ball 18 while permitting free rotation of the ball about a fixed centre namely, the centre of the ball 18. Provided with a diametrically extending bore 26, the ball 18 is adapted to receive a supporting shear shaft 28 integral with the blade 14 adjacent its inboard end. The shear shaft 28 is slideable within the ball 18 along a pitch axis of the blade 14 and is pivotable about lag and flapping axes which intersect at the centre of the ball.

The retention mechanism 16 also includes a resilient bearing 30 having a centre substantially concentric with the centre of the ball 18. Interposed between inboard and outboard support elements 32 and 34, respectively, the resilient bearing 30 (see especially Figure 3) is composed of a plurality of concentric part-spherical plates 36 and elastomer 38 bonded together in alternate layers. The outboard element 34 is integral with the support member 22 and the inboard element 32 is fixed to an end part 40 forming with a link part 42 an inward extension of the blade 14.

It is apparent, especially in Figure 1, that the resilient bearing 30 is so mounted that the centrifugal force exerted by the blade 14 in response to rotation of the hub member 12 results in compression of the elastomer 38. The layers of the elastomer 38 are sufficiently thin as to enable the resilient bearing 30 to withstand high normal pressures without bulging outwardly, that is, deflecting outwardly or in directions transverse to the centrifugal force. Further, as the blade 14 pivots about its flapping and lag axes or as a suitable pitch link 44 (Figure 2) is operated to rotate the blade about its pitch axis, the alternate plates 36 and elastomer 38 deflect in shear in a manner which is substantially independent of the compressive forces. Thus, the retention mechansism 16 provides for required blade motions while restraining the high centrifugal loads imparted by the blade. Specifically, the resilient bearing assumes all axial loads and the universal bearing carries all loads transverse to the pitch axis. As an additional feature, it can be seen that should the resilient bearing 30 fail, the interlocking arrangement of the support member 22 and the extension 40 provides a substantially fail-safe construction preventing the blade 14 from flying off in a radial direction.

To prevent binding between the blade 14 and the hub member 12 when the blade is in maximum elevated or depressed positions, a roller 46 is suitably mounted on the extension 40 coaxial with the pitch axis of the blade 14. When the blade 14 assumes its maximum elevated position, the roller 46 engages a flap stop 48 integral with the hub member 12 and when the blade 14 assumes a maximum depressed position, the roller 46 engages a droop stop 50 integral with the hub member 12. The flap stop 48 and the droop stop 50 are preferably conical in shape in order to accommodate pivoting of the blade 14 about its lag axis when the roller 46 is engaged with either the flap stop 48 or the droop stop 50.

To dampen motion of the blade 14 about its lag axis, a suitable damper 52 extends between a lug 54 integral with the support member 22 for an adjacent blade 14 and a suitable universal joint 56 mounted on the extension 40 substantially concentric with the pitch axis of the blade 14. In this manner, the damper 52 is effective to dampen movement of the blade 14 about its lag axis, and is substantially unaffected by movements of the blade 14 about its pitch and flapping axes.

An additional feature of the novel hub construction just disclosed resides in the smaller effective flapping mass present as compared with conventional constructions. That is, a considerable proportion of the mass, including the resilient bearing 30, the inboard support element 32, the extension 40, the roller 46, the damper 52 and the universal joint 56, is positioned inboard of the universal bearing 17 and partially balances the blade 14 and its as-

sociated structure about the ball 18. Specifically, the mass of those elements located inboard of the ball 18 provide a counter-clockwise moment (Figure 1), which partially offsets clockwise moments of the blade 14 about the ball 18 and aids substantially in reducing the vertical shaking forces and thus the level of vibration.

While the invention has been described and illustrated with reference to a preferred embodiment, it is to be understood that various changes may be made without departing from scope of the invention as defined in the appended claims.

WHAT WE CLAIM IS:—

1. A rotor assembly for a vertical lift aircraft, comprising a rotatable hub member, a rotor blade adapted to provide lift to said aircraft upon rotation of said hub member, retention means mounting said blade on said hub member and including a universal bearing having a fixed centre and supporting said blade for pivotal movement about a lag axis and about a flapping axis and for rotation about a pitch axis, said axes intersecting at said fixed centre, and a resilient bearing restraining said blade against centrifugal forces imposed in response to rotation of said hub member and co-operating with said universal bearing to permit pivotal and rotational movement of said blade about said fixed centre.

2. A rotor assembly as set forth in claim 1 wherein said universal bearing includes a socket fixed to said hub member and a ball rotatably mounted in said socket and said blade includes a supporting shaft rotatable with said ball and longitudinally movable relative to said ball.

3. A rotor assembly as set forth in claim 2 wherein said hub member includes a central portion and a support member spaced outwardly from said central portion, the said socket being fixed to said support member, said blade shaft being integral with the blade and engaged with said ball, an extension of the blade shaft extending intermediate said central portion and said support member, and the resilient bearing being mounted between said extension and said support member.

4. A rotor assembly as set forth in any of claims 1 to 3 wherein said resilient bearing includes a plurality of part-spherical plates and elastomer bonded together in alternate layers so as to be generally concentrated with said fixed centre.

5. A rotor assembly as set forth in any of the preceding claims wherein said hub member includes a droop stop and a flap stop and said blade includes a roller engageable with said droop stop to define a lower limit of movement of said blade about said flapping axis and engageable with said flap stop to define an upper limit of movement of said blade about said flapping axis.

6. A rotor assembly as set forth in any of the preceding claims wherein said blade includes a universal joint fixed to said blade substantially coaxial with said pitch axis and including damper means extending between said hub member and said joint and adapted to dampen movement of said blade about said lag axis but substantially ineffective to dampen movement of said blade about said pitch and flapping axes.

7. A rotor assembly substantially as herein described with reference to the accompanying drawings.

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1235277 COMPLETE SPECIFICATION

1 SHEET

This drawing is a reproduction of the Original on a reduced scale

Fig. 1.

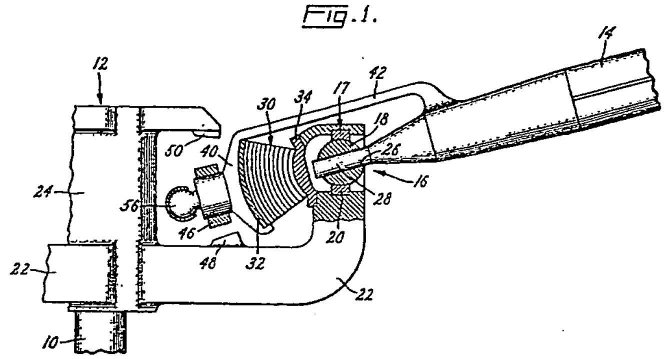

Fig. 2.

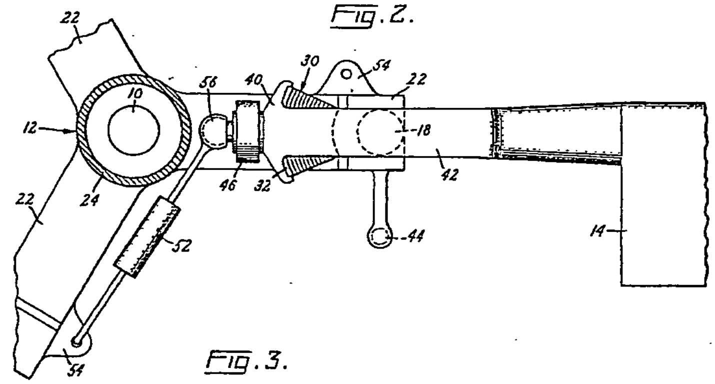

Fig. 3.